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Effect of smoking on intraoperative sputum and postoperative pulmonary complication in minor surgical patients

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Summary The effect of smoking for postoperative pulmonary complications (PPCs) in minor surgical patients who have an early recovery has not been evaluated. Smoking may also affect intraoperative sputum volume. We thus evaluated whether smoking had a relation to intraoperative sputum volume or PPCs in minor surgical patients. Smoking status was determined through the interviewer-assisted questionnaires. Intraoperative sputum volume was judged using the number of trials to suck up sputum from the trachea. Current and Ex-smokers were significantly more likely to have an increased intraoperative sputum volume when compared with Non-smokers (18.3% and 17.9% vs. 9.4%) although the relationship between smoking and PPCs was not demonstrated. In the multivariate models, Current and Ex-Smokers was identified as an independent risk factor of an increased intraoperative sputum volume (odds ratio, 2.7; 95% confidence interval, 1.6–4.6). The patients with <2 months smoking cessation were more likely to have an increased intraoperative sputum volume. In conclusion, smoking is the risk factor of an increased intraoperative sputum volume, and preoperative smoking cessation $\geqslant 2$ months is recommended to reduce the risk of an increased intraoperative sputum volume, although the relationship between smoking and PPCs was not elucidated in minor surgical patients.

Introduction

Smoking is well known to be a risk factor for surgical patients contributing to the development of postoperative pulmonary complications (PPCs).[1] Previous studies reported that current smokers were two–six times more likely to develop PPCs than non-current smokers.[2–4] However, these studies may be intended for patients undergoing major surgery including abdominal or thoracic surgery who are likely to have a reduced pulmonary function[5] and a prolonged bed rest following surgery. The effect of smoking for the development of PPCs in patients undergoing minor surgery who have an early recovery following surgery has not been evaluated.

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On the other hand, smoking contributes to an increased sputum volume due to mucous hypersecretion[6,7] and decreased ciliary activity.[8–10] An increased sputum volume may cause the development of some troubles related with respiratory system during intraoperative period, for example, an unexpected rise in airway pressure, a deterioration of systemic oxygenation, and so on. An appropriate management for such airway conditions is required to prevent the development of not only intraoperative pulmonary troubles but also PPCs. So it is informative for surgical patients and clinicians to evaluate the relationship between preoperative smoking habits and intraoperative sputum volume.

We thus evaluated whether preoperative cigarette smoking habits had a relation to intraoperative sputum volume or PPCs in minor surgical patients undergoing general anesthesia.

Methods

Study population

This study protocol was approved by the local ethical committee, Iwaki Kyoritsu General Hospital, Fukushima, Japan. We performed the prospective cohort study on the consecutive patients undergoing elective minor surgery which was planned to walk or have a meal from the first postoperative day, including eye, ear, nasopharyngeal, oral, neck, superficial, and orthopedic surgery, under general anesthesia with their tracheae intubated from November 2000 to January 2002. Excluded from this study were patients who had problem of consciousness, who had heart failure, whose tracheae were intubated or tracheostomized before surgery, and whose tracheae were planned to be tracheostomized during surgery. After all, consecutive 1011 patients were enrolled in this study.

Preoperative cigarette smoking habits

The following smoking-related data were obtained for each patient through the interviewer-assisted questionnaires a day before surgery: smoking habits (Current, Ex- or Non-smoker), total pack-years smoked (one pack-year was defined as 20 cigarettes per day for 1 year), and the duration of smoking-free period before surgery. Current smoker was defined as a person who had smoked until the day of the interview. Ex-smoker was defined as a person who had stopped smoking before the day of the interview. Non-smoker was defined as a person who had never smoked.

Intraoperative sputum volume

Intraoperative sputum volume was judged using the number of trials to suck up sputum from the trachea at the end of surgery. We used an original scale: 0 = no sputum was sucked up, 1 = sputum was all sucked up on the first aspiration trial only, 2 = twice or more aspiration trials were needed to suck up sputum, 3 = sucking up sputum was needed during surgery in the case of problems associated with an increased sputum volume, and the troubles were improved by sucking up sputum. Intraoperative sputum volume was defined as increased when the scale was 2 or 3.

Postoperative pulmonary complications (PPCs)

The development of PPCs was defined as present when the patients met the following criteria during the first postoperative 30 days period or until they were discharged; (1) bronchoconstriction: the presence of wheezing associated with dyspnea or arterial oxygen saturation $<95\%$ under oxygen 5 l/min via face mask, and the use of bronchodilator medication (aerosol treatment using salbutamol, intravenous aminophylline 5 mg/kg, or intravenous hydrocortisone 125 mg), (2) atelectasis: the evidence of pulmonary atelectasis on chest radiograph associated with dyspnea or arterial oxygen saturation $<95\%$ under oxygen 5 l/min via face mask, (3) pulmonary infection: the presence of pulmonary infiltration on chest radiograph with the signs of systemic infection (body temperature $\geqslant 38.0\,^{\circ}C$ and leukocytosis or leukopenia), (4) postoperative tracheal reintubation due to respiratory failure, and (5) death related to pulmonary complications.

Confounders

The following patient- and surgery-related data were obtained through the standardized questionnaires, medical records, and physical examinations: gender, age, body mass index (weight in kilograms divided by height in meters squared), American Society of Anesthesiologists (ASA) physical status, pre-existing history of pulmonary diseases, pre-existing history of chronic obstructive pulmonary disease (COPD), abnormal findings of preoperative chest radiograph, preoperative medication (use of aminophylline or steroid), respiratory-related symptoms (chronic cough and sputum production), type of surgery, method of anesthesia, duration of surgery, duration of intubation, use of anti-cholinergic agent before the sputum volume evaluation, and the season in the year of the surgery done (cold season was defined as November–April which was half a year of the maximum temperature below 16 °C in the area around the hospital).

Statistical analysis

According to preoperative smoking habits, patients were divided into the three groups (Current, Ex- and Non-smokers). The numbers of patient with an increased intraoperative sputum volume or PPCs among Current, Ex- and Non-smokers, respectively, were determined by frequency distributions. Analysis of variance was used to compare the continuous variables. Chi-Square test (or Fisher's exact test, where appropriate) was used to compare the categorical variables. Logistic regression analysis was used to determine the significant predictors of an increased intraoperative sputum volume or PPCs. All variables suggested to have a relationship with an increased intraoperative sputum volume or PPCs in the univariate analysis ($P<0.1$) were included for the multivariate logistic regression analysis.

Computer statistical application, Stat-View, ver.5 (SAS Institute, Cary, NC), was used for the statistical analysis. $P<0.05$ was considered as statistically significant.

Results

Three patients were excluded from the study because the patients underwent unplanned tracheostomy intraoperatively due to glottic stenosis related with laryngeal tumor. Therefore, 1008 patients were included for statistical analysis. Table 1 shows the demographic data. Most of Current and Ex-smokers were male, but most of Non-smokers were female. The frequency of pre-existing history of pulmonary disease or COPD was not statistically different among three groups, but Current and Ex-smokers were significantly more likely to have respiratory-related symptoms when compared with Non-smokers. Type of surgery and method of anesthesia were similar among three groups, but Non-smokers had longer duration of surgery and intubation than Current and Ex-smokers.

Table 2 shows the relationship between preoperative smoking habits and intraoperative sputum volume or PPCs. Current and Ex-smokers were significantly more likely to have an increased intraoperative sputum volume when compared with Non-smokers (18.3% and 17.9% vs. 9.4%, $P<0.005$ and $P<0.001$, respectively). Eight Ex-smokers and three Non-smokers in patients with an increased intraoperative sputum volume needed to suck up sputum during surgery because of an unexpected rise in airway pressure or oxygen desaturation that were improved by sucking up sputum. In these patients, 4 Ex-smokers and 2 Non-smokers were patients with preoperative history of pulmonary disease. The incidence of PPCs was not statistically different among the three groups. However, the incidence of PPCs in 140 patients who had an increased intraoperative sputum volume was significantly greater than that in 868 patients who did not (6.4% vs. 0.8%, $P<0.0001$).

The relationship between the duration of smoking-free period and the risk of an increased intraoperative sputum volume is shown in Table 3. Current smokers and Ex-smokers who had <2 months smoking-free period were more likely to have an increased intraoperative sputum volume when compared with Non-smokers. Especially, Ex-smokers with <2 weeks smoking-free period had high incidence of an increased intraoperative sputum volume. The relationship between the duration of smoking-free period and the risk of PPCs was not evaluated because the number of patients with PPCs is insufficient to analyze statistically.

The variables related with an increased intraoperative sputum volume in the univariate analysis ($P<0.1$) are shown in Table 4. Current and Ex-smokers had significant risk for an increased intraoperative sputum volume than Non-smokers. In Current and Ex-smokers, patients with total pack-years smoked $\geqslant 20$ were more likely to have an increased intraoperative sputum volume although not significantly. Multivariate analysis was performed to find independent predictors of an increased intraoperative sputum volume using the variables listed in Table 4. Current and Ex-smokers (vs. Non-smokers) (odds ratio [OR], 2.7; 95% confidence interval [CI], 1.6–4.6), pre-existing history of pulmonary diseases (OR, 2.1; 95% CI, 1.0–4.4), pre-existing history of COPD (OR, 3.3; 95% CI, 1.3–8.5), abnormal findings of chest radiograph (OR, 4.7; 95% CI, 2.3–9.8), cold season at surgery (OR, 2.4; 95% CI, 1.6–3.8), were significantly independent predictors of an increased intraoperative sputum volume.

Table 1 The demographic data in this study.

	Current smokers ($n = 159$)	Ex-smokers ($n = 369$)	Non-smokers ($n = 480$)
Male gender	124 (78.0)*	301 (81.6)*	106 (22.3)
Age (yr)¶¶	40.9 ± 16.6	51.8 ± 18.0	58.0 ± 16.7
BMI (kg m^{-2})	23.4 ± 3.9***	23.4 ± 3.7***	24.2 ± 3.5
ASA			
1	92 (57.9)	149 (40.4)	168 (35.0)
2	63 (39.6)	213 (57.7)	299 (62.3)
3	4 (2.5)	7 (1.9)	13 (2.7)
History of pulmonary disease	11 (6.9)	42 (11.4)	49 (10.2)
History of COPD	5 (1.3)	16 (3.3)	24 (3.1)
Abnormal findings of chest X-ray	8 (5.0)	21 (5.7)	27 (5.6)
Preoperative medication			
Aminophylline	1 (0.6)	6 (1.6)	4 (0.8)
Steroid	0 (0)	0 (0)	1 (0.2)
Respiratory-related symptoms			
Chronic cough	30 (18.9)**	62 (16.8)**	43 (9.0)
Sputum production	47 (30.0)*¶	78 (21.1)*	50 (10.4)
Type of surgery			
Eye	3 (1.9)	4 (1.1)	13 (2.7)
Ear	7 (4.4)	6 (1.6)	13 (2.7)
Nasopharyngeal	24 (15.1)	77 (21.0)	66 (13.8)
Oral	10 (6.3)	31 (8.4)	35 (7.3)
Neck	10 (6.3)	54 (14.7)	26 (5.4)
Superficial	8 (5.0)	35 (9.5)	86 (17.9)
Orthopedic	97 (61.0)	162 (43.9)	241 (50.2)
Method of anesthesia			
General	36 (22.6)	87 (23.6)	102 (21.3)
General + fentanyl	100 (62.9)	232 (62.9)	275 (57.3)
General + morphine	4 (2.5)	15 (4.1)	16 (3.3)
General + pentazocine	6 (8.2)	8 (7.3)	9 (16.3)
General + epidural	13 (3.8)	27 (2.2)	78 (1.9)
Duration of surgery (min)	91.0 ± 63.9**	97.5 ± 71.8**	112.6 ± 69.4
Duration of intubation (min)	131.5 ± 70.3**	139.9 ± 76.8**	156.9 ± 75.5
Use of anti-cholinergic agent	30 (18.9)	74 (20.1)	79 (16.5)
Cold season at surgery done	85 (53.5)	213 (57.7)	288 (60.0)
Total pack-years smoked ⩾20	68 (42.8)¶	197 (53.4)	

Figures are mean ± SD, or the number of patients in the group (%).
$^{*}P<0.0001$, $^{**}P<0.01$, $^{***}P<0.05$ vs. non-smokers; $^{¶}P<0.05$ vs. ex-smokers. $^{¶¶}P<0.0001$ among three smoking groups.

Table 5 showed the variables related with the development of PPCs in the univariate analysis ($P<0.1$). Multivariate analysis was performed to analyze independent risk factors of PPCs using the variables listed in Table 5. Pre-existing history of pulmonary diseases (OR, 12.6; 95% CI, 3.2–49.6), chronic cough (OR, 4.3; 95% CI, 1.2–15.6), were significantly independent risk factors of PPCs.

Discussion

We found that preoperative smoking habit was significantly related with an increased intraoperative sputum volume in minor surgical patients undergoing general anesthesia. Current and Ex-smokers were approximately twice more likely to have an increased intraoperative sputum volume

Table 2 The relationship between preoperative smoking habits and intraoperative sputum volume or PPCs.

	Current smokers ($n = 159$)	Ex-smokers ($n = 369$)	Non-smokers ($n = 480$)
Intraoperative sputum volume			
0	82	197	308
1	48	106	127
2	29	58	42
3	0	8	3
Increased	29 (18.2)*	66 (17.9)**	45 (9.4)
PPCs			
Bronchoconstriction	3	4	8
Atelectasis	0	0	0
Pulmonary Infection	0	1	0
Reintubation	0	0	0
Total	3 (1.9)	5 (1.4)	8 (1.7)

Figures are the number of patients in the group (%).
*$P<0.005$ vs. non-smokers. **$P<0.001$ vs. non-smokers.

Table 3 The relationship between the duration of smoking-free period and the risk of an increased intraoperative sputum volume.

Duration of smoking-free period	No.	%	RR (95% CI)
None (current smokers)	29/159	18.2	1.9 (1.3–3.0)
<1 wk.	36/157	22.9	2.4 (1.6–3.6)
⩾1 wk. and <2 wk.	8/35	22.9	2.4 (1.2–4.8)
⩾2 wk. and <2 mo.	6/32	18.8	2.0 (0.9–4.3)
⩾2 mo.	16/145	11.0	1.2 (0.7–2.0)
Non-smokers	45/480	9.3	Reference group

RR: relative risk, CI: confidence interval.

Table 4 The variables related to an increased intraoperative sputum volume in univariate analysis.

Variable	OR (95% CI)	*P* value
Current and Ex-smokers (vs. Non-smokers)	2.1 (1.5–3.1)	0.0001
Total pack-years smoked ⩾20*	1.5 (0.9–2.3)	0.0983
Male gender	1.7 (1.2–2.4)	0.0057
ASA⩾3	3.9 (1.7–9.1)	0.0016
History of pulmonary disease	6.4 (4.1–10.0)	<0.0001
History of COPD	12.5 (6.6–23.6)	<0.0001
Abnormal findings of chest X-ray	9.6 (5.5–16.8)	<0.0001
Chronic cough	1.8 (1.1–2.8)	0.0144
Sputum production	2.2 (1.4–3.3)	0.0002
Cold season at surgery	2.3 (1.5–3.5)	<0.0001

OR: odds ratio, CI: confidence interval.
*Total pack-years smoked ⩾20 was analyzed in Current and Ex-smokers only.

than Non-smokers, and we identified as an independent risk factor in multivariate analysis. This finding came from mucous hypersecretion associated with airway inflammation[6,7] and decreased mucociliary clearance induced by the impairment of ciliated epithelium.[8–10] In Current and Ex-smokers, patients with total pack-years smoked ⩾20 were more likely to have an increased intraoperative sputum volume although not significantly. Previous findings have showed that the

Table 5 The variables related to PPCs in univariate analysis.

Variable	OR (95% CI)	*P* value
ASA$\geqslant$3	10.7 (2.8–40.3)	0.0005
History of pulmonary disease	21.8 (7.4–64.1)	$<$0.0001
History of COPD	14.7 (5.1–42.4)	$<$0.0001
Abnormal findings of chest X-ray	8.4 (2.8–25.0)	0.0001
Chronic cough	6.8 (2.5–18.5)	0.0002
Sputum production	3.8 (1.4–10.4)	0.0088
Cold season at surgery	3.2 (0.9–11.2)	0.0732

OR: odds ratio, CI: confidence interval.

extent of pack-years smoked had correlation with the ratio of CD8 + T-lymphocytes playing a central role in small-airway inflammation to total T-lymphocytes[11] and the decrease of mucociliary clearance.[12]

In this study, we could not elucidate the relationship between preoperative smoking habits and PPCs. Previous studies have reported that current smokers were two–six times more likely to develop PPCs than non-current smokers.[2–4] The difference may be due to the study population. These studies have been intended for patients undergoing major surgery including abdominal or thoracic surgery who are apt to have a reduced pulmonary function[5] and a prolonged bed rest following surgery, and the incidence of PPCs has been reported to be approximately 20%. Our study population was patients undergoing minor surgery who have an early recovery following surgery, and the incidence of PPCs was under 2%. Recent study has demonstrated a low risk of PPCs in smokers undergoing joint replacement surgery, probably because of the distance of the operation site from the diaphragm and early mobilization.[13] Preoperative respiratory training using Inspirex (incentive spirometer) and aerosol treatment using bromhexine hydrochloride for patients with smoking might also influence our results. However, it is supposed that preoperative smoking habits is the risk factor of PPCs even for minor surgical patients because the incidence of PPCs in patients who had an increased intraoperative sputum volume was significantly greater than that in patients who did not.

Current smokers and Ex-smokers who had $<$2 months smoking-free period were more likely to have an increased intraoperative sputum volume when compared with Non-smokers. This result is consistent with previous findings. It has been reported that sputum volume declines over a 6-week period after smoking cessation.[6] Rennard et al.[14] has showed a beneficial effect of smoking reduction for 2 months in reducing airway inflammation. Moreover, this result is compatible with the report which has recommended 2 months smoking cessation to reduce the risk of PPCs.[15] Therefore, preoperative smoking cessation at least $\geqslant$2 months is recommended to reduce the risk of an increased intraoperative sputum volume. On the other hand, Ex-smokers with $<$2 weeks smoking-free period had high incidence of an increased intraoperative sputum volume. A transient increased sputum volume in several days after smoking cessation has been reported.[6] Our result may support the finding that reduction of cigarette consumption closer to the time of surgery increased the risk of PPCs.[4] However, short-term preoperative smoking cessation may benefit surgical patients by reducing blood carbon monoxide levels.[16] The influence of short-term preoperative smoking cessation on clinical outcomes after surgery remains unclear.

Other predictors related with an increased intraoperative sputum volume included male gender, ASA$\geqslant$3, pre-existing history of pulmonary diseases, pre-existing history of COPD, abnormal findings of preoperative chest radiograph, chronic cough, sputum production, and cold season at the surgery. Male gender might be identified because most of Current and Ex-smokers were male. Respiratory-related histories and symptoms were identified as risk factors. For such patients, we have to note an increased intraoperative sputum volume, and carry out an appropriate airway management to prevent the development of PPCs. On the other hand, cold season at the surgery was identified. Most of cold season defined in this study corresponds to winter season in Japan, and its dry and cold weather condition may tend to cause an airway inflammation.[17] Clinicians should consider that surgical patients at the time of weather like winter have a risk for an increased intraoperative sputum volume.

Predictors related with the development of PPCs were ASA$\geqslant$3, pre-existing history of pulmonary diseases, pre-existing history of COPD, abnormal findings of preoperative chest radiograph, chronic cough, and sputum production. Brooks-Brunn[18] has demonstrated ASA$\geqslant$3 as one of independent risk factors of PPCs after abdominal surgery, and some investigators have suggested that comorbidity was good indicator.[19,20] Pre-existing history of pulmonary disease and chronic cough were identified as independent risk factors in our study, but pre-existing history of COPD was not identified. Pre-existing history of COPD has been identified previously as an independent risk factor of PPCs after various surgeries.[4] Another finding using respiratory symptoms and physiology as risk factors has demonstrated impaired pulmonary function measured via spirometry and current mucous hypersecretion as independent predictors of PPCs.[21] Potential explanation of the difference may be that most of PPCs were bronchoconstriction in our study. We did not include pulmonary function testing as a risk factor because it was not done routinely on all patients undergoing minor surgery.

The limitations of our study were the following two points. First, intraoperative sputum volume was judged using the number of trials to suck up sputum from the trachea. It would have been better to measure the real sputum volume in ml. But our method is simple and easy to understand. Second, sputum quality might have to be also considered because purulent sputum is usually due to current pulmonary or infectious disease. Further study that also includes sputum quality evaluation will help to make the strategy of perioperative airway management.

In conclusions, Current and Ex-smokers have an increased risk for an increased intraoperative sputum volume, and preoperative smoking cessation at least $\geqslant$2 months is recommended to reduce the risk of an increased intraoperative sputum volume although the relationship between preoperative smoking habits and PPCs was not demonstrated in minor surgical patients undergoing general anesthesia.

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